4. DESCRIPTION OF MONITORED TESTING

The most widely used automatic corrosion-rate measurement system relies on both conductive and nonconductive E/R corrosion probes, which can be used in any environment (i.e., liquid, gas, or solid). The probes measure the thinning (general corrosion) of the sample electrode (metal strip) by an increase of the electrical resistance of the sample electrode in comparison with the reference electrode, which is protected from corrosion. This technique is especially sensitive to pitting corrosion near the end of the probe's life. An advantage of the use of E/R probes is that they do not require removal from the ground to measure corrosion rates. In addition, the probes provide remote corrosion rate measurements and permit online data collection. Measurements obtained from E/R probes can be directly compared with the direct corrosion coupons corrosion rates as the coupon are recovered and analyzed.

4.1 Equipment

The E/R probes provide real-time, remote measurement of the corrosion rates of selected materials of interest. The typical probe design uses two thin metal strips that serve as electrical elements, one exposed to corrosion and one protected. In each probe, the two strips are composed of the metal being tested for corrosion. The corrosion measurement is based on the increase in electrical resistance in the exposed elements, caused by the thinning from corrosion and degradation. The change in resistance is calibrated to a corrosion rate through the use of an electrical bridge circuit that compares resistance in the corroding test strip to that in the protected one. In the particular probe type used in this test, the thin metal strip consists of a small thin plate, cut (i.e., etched) to form a relatively longer "path" than is possible with the rectangular strip. Figure 37 shows representations of both kinds of probes.

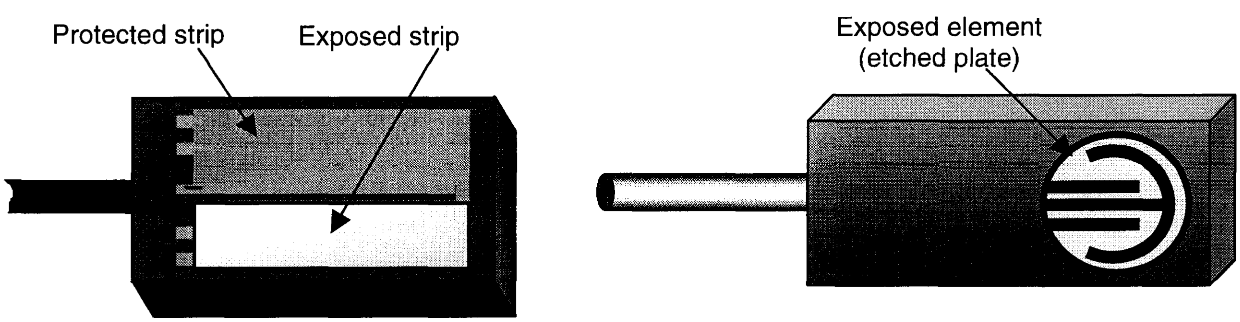

Figure 37. Sketches showing two types of electrical resistance probes. In one, the electrical element is a thin rectangular strip of the metal being tested for corrosion. In the other, an etched plate is used instead.

4.2 Probe Selection and Preparation

The LTCD test uses E/R probes to assess corrosion rates in the following materials: low-carbon steel, Type 304L stainless steel, Type 316L stainless steel, Inconel 718, Aluminum 6061, and Zircaloy-4. Ferralium 255 is not included in the monitored testing because a Ferralium E/R probe with a thin metal strip is not available at a cost-effective price, and because Ferralium buried at the SDA is in the form of a waste container, not an activated metal. Beryllium S200F is also excluded from the monitored testing because acquisition of beryllium E/R probes would require contracting with Brush-Wellman (the Beryllium S200F vendor) to supply the material to the E/R probe manufacture's element specification, resulting in a very long lead time before the probe could be supplied. Further, beryllium has not been previously used as an E/R probe material, so the results would be experimental. Welded Type 316 stainless steel is also excluded from this part of the testing because the nature of the thin metal strips in the E/R probes precludes the use of welded metal materials.

Before installation, the E/R probes and other instrumentation are assembled to form a probe array and pre-tested. The probe arrays permit manual and automated data collection. A single probe array consists of one E/R probe for each of the six metals of interest, one time domain reflectrometry (TDR) probe for moisture monitoring, and one or two thermocouples for temperature monitoring, along with the associated wiring.

4.3 Test Conditions

The test conditions for the monitored testing will provide corrosion rate information for a variety of conditions with particular emphasis on soil moisture. Some probe arrays will be exposed to supplemental moisture, while others will be exposed only to the natural environmental conditions, namely, the naturally occurring weather conditions at the SDA. These are the conditions that generally govern corrosion rates at the SDA. Like the direct corrosion test coupons for those probes subjected to natural conditions, precipitation and soil moisture are also monitored, but no attempt is made to control or alter the moisture that the coupons are exposed to.

For probes exposed to supplemental moisture, controlled application of water to the ground surface at these locations permits measurement of corrosion rates, as influenced by the resulting high moisture levels. Monitoring the soil moisture by TDR probes at these locations is complemented by neutron probe data collected from nearby neutron probe access tubes. The test plan also calls for the use of suction lysimeters to collect soil water samples for analysis of soil water chemistry. The corrosion monitoring with supplemental moisture is included in the test program because high moisture is one of the variables that can significantly affect corrosion rates. High moisture levels are known to occur in the SDA at some locations, typically where water ponds from spring snowmelts and heavy rainstorms.

4.4 Probe Array Emplacement

The LTCD test plan calls for deployment of up to seven probe arrays. One probe array will be reserved for possible placement in the mound for testing specific environmental conditions. The other six will be placed in the berm. Most of the probe arrays will be placed at the 4-ft depth. At least one probe array will be placed in the berm at a depth of 10 ft. At least two probe arrays will be subjected to application of supplemental moisture, in addition to natural precipitation, to evaluate the effects of additional moisture on the corrosion rate. Table 5 provides details about probe array placement locations, test conditions, and schedule.

Table 5. Probe array locations, conditions, and placement.

Probe Array	Test Conditions	Depth (ft)	Installation Date	Berm Location
PA01	Supplemental precipitation	4	To be determined	X
PA02	Supplemental precipitation	4	To be determined	IX
PA03	Natural precipitation	4	To be determined	VIII
PA04	Natural precipitation	4	To be determined	VII
PA05	Natural precipitation	10	October 23, 2000	II
PA06	Natural precipitation	4	October 26, 2000	II
PA06	To be determined	4	To be determined	Mound

Typical installation of a probe array is in a location of its own, with the arrangement shown in Figure 38. A 2-ft diameter hole will be sufficient in this case. Procedures for placement, back filling, and compaction are the same for the probe arrays as for the coupon arrays.

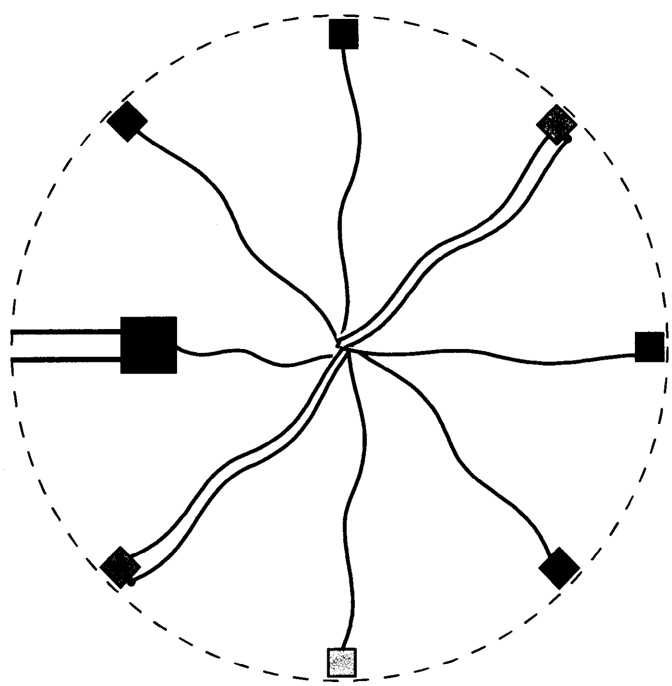

Figure 38. Configuration of a probe array.

Another option for installing probe arrays is to install six probes, one TDR, and one thermocouple along with a coupon array at either the 10-ft depth or the 4-ft depth. This option allows direct comparison of probe results with coupon corrosion. Coupons and probes placed at the same location would be the last ones retrieved and the probes would be retrieved for examination along with the coupons. Figure 39 shows an arrangement used for placement of probes and coupons at the same location and depth.

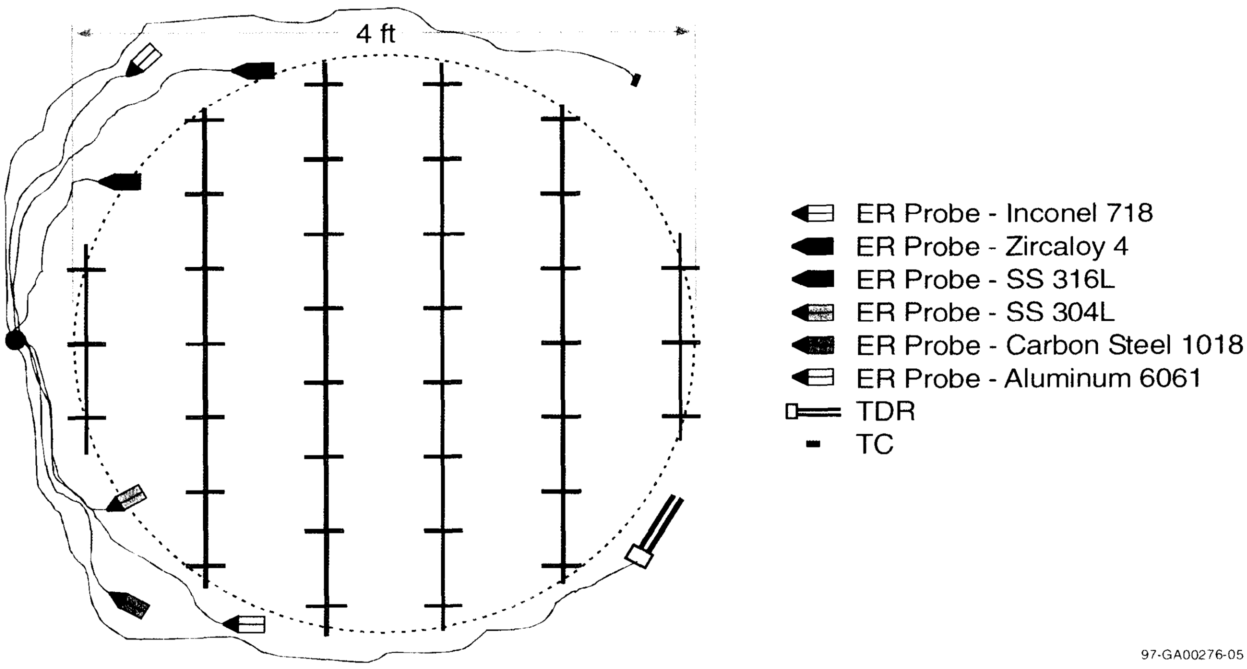

Figure 39. Arrangement for placing a coupon array and a probe array together at the same location and depth.

4.5 E/R Probe Monitoring

The data from the E/R probes can be retrieved manually or sent to a data logger. When the data logger is used, data from the probes, the thermocouples (measuring soil temperature) and the TDR probe (measuring soil moisture) are read at a time interval of once per day. When the manual system is used, data are taken less frequently, typically, once per week or once per month. The operation of, and data collection from, the E/R probes are governed by ASTM Method G 96.

The test plan calls for installation of six probe arrays at the berm in Fiscal Year 2001. However, funding was eliminated, so only two probe arrays were installed in the fall of 2000. Continued funding limitations preclude acquiring data from both arrays. The thermocouples and TDRs have not been connected to the data logger and the installed E/R probes have only been tested for system operability. When and if funding becomes available, the data from the instruments will be collected and validated at a later date.

5. CHARACTERIZATION RESULTS

The LTCD test calls for analysis of soil samples collected along with the coupons at coupon retrieval. Funding for activities related to soil characterization for physical, chemical, and hydraulic properties was limited. Microbiological analysis was performed on selected coupon surfaces and on soil attached to the 3-year coupons at removal. Also analyzed was the soil adhering to the beryllium coupons from the 10-ft depth. The following subsections present the results.

5.1 Soil Characterization

Two soil samples at the 4- and 10-ft depths were collected (for a total of eight samples) during both installation and retrieval solely for determination of volumetric moisture contents. The results are summarized in Table 6. The sample locations were similar for both depths; the first being on the northern side of the hole and the second being on the southern side of the hole.

Clearly the 4-ft depth is drier than the 10-ft depth, which may account for the generally increased corrosion rates observed at the 10-ft depth. The difference in moisture content with depth is attributed to the use of moisture in the construction of the berm, which continues to equilibrate with the current environment. Moisture at the 4-ft depth has moved up and out of the system in response to the hydraulic gradient, while moisture at the 10-ft depth is consistent. This is probably a result of an upward hydraulic gradient existing less frequently at the 10-ft depth than at the 4-ft depth. Insufficient moisture data are available to identify the actual causes. More moisture and soil tension data are needed for increased confidence and understanding of the actual hydraulic system at the berm.

Table 6. Soil sample moisture analysis.

	Recovery	
Sample Number	Depth - Location	Volumetric Moisture Contents (%)
1	4 ft - North	12.8
2	4 ft - South	12.6
3	10 ft - North	18.6
4	10 ft - South	16.5
	Installation	
Sample Number	Depth - Location	Volumetric Moisture Contents (%)
5	4 ft - North	14.6
6	4 ft - South	12.9
7	10 ft - North	15.7
8	10 ft - South	15.8

5.2 Microbiological Characterization

Microbial sampling and analysis were performed on the coupons retrieved after 3 years of exposure. The results and observations presented here are intended to supplement the first year data and support efforts to determine whether these microbes are influencing the corrosion reactions. For this study, isolation of microbes and analysis of the soil atmosphere are used as indicators of microbial activity associated with the buried coupons. Procedures used for isolation of microbes associated with the surface of the test coupons were the same (except phenol red solid media was not used) as those used in the first year sampling (see Appendix B in Mizia et al. 2000). Soil gas sampling was not conducted during this sampling period because of funding restrictions.

The 3-year coupon recovery differed slightly from the 1-year coupon recovery. During the 1-year recovery, individual coupon arrays were retrieved with surrounding soil and transported to the lab in transport boxes where microbial sampling of the soil and coupons took place in a controlled laboratory environment. The 3-year recovery eliminated the use of the transport boxes and after an array was uncovered at the test location, the surrounding soil was aseptically removed from the individual coupons. The exposed array was then placed into one or more sterilized plastic bags, sealed with tape, and transported to the laboratory. This procedure change increases the importance of performing the microbial isolation as soon as possible after recovery. The coupons from the 4-ft depth were recovered on October 19, 2000, and microbial work commenced on October 23, 2000. The coupons from the 10-ft depth were recovered on October 23, 2000, and microbial efforts were completed on October 24, 2000.

Microbial samples were collected from imprints (placing each specimen onto the surface of solid agar and then removing) and swabbing (Teflon washers and each coupon from an array support rod). The specimens were handled with a sterilized hemostat. Before removal from the array rod, any adhering soil was lightly scraped from individual coupons. Care was required in handling the beryllium and carbon steel coupons as they were incrusted with adhering soils and observable corrosion. To a lesser degree, the aluminum coupons also had some adhering soil (that was easily removed) and some patches of visible corrosion. The stainless steels, Ferralium 255, Zircaloy-4, and Inconel 718 coupons were free of soil or visual corrosion and appeared to be in a bright and shiny condition.

In addition to microbial samples, four soil samples for determination of soil moisture were retrieved from both the 4- and 10-ft depths. The samples (approximately 100 g) were placed in tared containers and dried 48 hours at 100°C. Based on weight loss, the percent moisture was calculated on a dry soil basis. The percent moisture of the soil in proximity of the coupons was found to be $11.5 \pm 0.7\%$ at the 4-ft depth and $13.9 \pm 1.9\%$ at the 10-ft depth. Microbial colony forming units (cfu) were also isolated at both depths, and the cfu numbers ranged from 1.1×10^6 to 4.4×10^8 at the 4-ft depth to 1.2×10^6 to 9.8×10^6 at the 10-ft depth.

Given the above soil conditions, it was not surprising that microbes were found to be associated with the surfaces of the recovered coupons. Examination of inoculated agar plates and liquid media (i.e., Bacto Bottles) after 24 hours confirmed the presence of microbes on the surfaces of all the recovered coupons and Teflon rings. The imprints of all coupons and rings made on the solid media (i.e., nutrient agar plates) were easily discernable within the boundary of each imprint as the result of heavy microbial growth. This growth included species of bacteria, actinomycetes, and fungi.

The beryllium coupons continued to support microbial growth. This finding is of interest given the lack of information about beryllium effects on microbial growth. While no effort was made to calculate the concentration of microbes associated with coupon surfaces, the data reemphasize that neither the beryllium nor any of the other metals had any marked biocidal effects.

The occurrence of specific types of coupon born microbes was made using selective liquid medium (i.e., Bacto Bottles). Data from coupons at the 4- and 10-ft depths are seen in Table 7 and Table 8, respectfully. Heterotrophic microbes (those that use organic carbon) were isolated from every one of the coupons, but denitrifiering microbes were completely absent. Most of the coupons had organic acid producing microbes present, but there were no instances of mineral acid producers (i.e., *T. thiooxidans*).

A change from the 1-year examination was the discovery of sulfate reducing bacteria (SRB) (associated with biocorrosion of metals) on various carbon steel and aluminum coupons. More significant, however, was SRB occurrence on three of the beryllium coupons. While SRBs were isolated previously from the soil, none were isolated from coupons from the first recovery. This change indicates that these coupon materials are susceptible to biocorrosion. In comparing the data from Table 7 with the data from Table 2 (see Section 3), of the seven coupons with SRBs recovered, six have the highest corrosion rates for similar coupon composition. The activity of the SRBs could have a significant impact on the calculated rate of metal corrosion in SDA soils.

5.3 Adhering Soil Chemical Analysis

Soil adhering to two of the four beryllium coupons from the 10-ft depth was collected for analysis. The samples were analyzed at the INTEC analytical laboratory for suspected corrosion products. Corrosion product analysis results, as reported by the analytical chemistry laboratory, are shown in Tables 9 and 10.

Table 7. Microbial types isolated from the surface of coupons retrieved from the 4-ft depth.

		Microbial Characteristics				
Sample	Metal Type	Heterotroph	SRB	Denitrifier	Acid Producer	*T. thio.*
CAO3-4-2	304L [a]	+	-	-	+	-
CAO3-4-4	304L [a]	+	-	-	+	-
CAO3-5-4	304L [a]	+	-	-	+	-
CAO3-6-3	304L [a]	+	-	-	+	-
CAO3-1-3	316L [a]	+	-	-	+	-
CAO3-4-3	316L [a]	+	-	-	-	-
CAO3-5-5	316L [a]	+	-	-	+	-
CAO3-6-1	316L [a]	+	-	-	+	-
CAO3-2-2	316L [a] Welded	+	-	-	-	-
CAO3-2-3	316L [a] Welded	+	-	-	+	-
CAO3-4-7	316L [a] Welded	+	-	-	+	-
CAO3-6-2	316L [a] Welded	+	-	-	+	-
CAO3-2-4	Aluminum	+	-	-	-	-
CAO3-3-1	Aluminum	+	-	-	+	-
CAO3-3-7	Aluminum	+	-	-	+	-
CAO3-5-7	Aluminum	+	-	-	+	-
CAO3-2-1	Beryllium	+	-	-	+	-
CAO3-2-6	Beryllium	+	-	-	+	-
CAO3-4-6	Beryllium	+	-	-	+	-
CAO3-5-2	Beryllium	+	+	-	+	-
CAO3-1-2	Carbon Steel	+	-	-	+	-
CAO3-3-2	Carbon Steel	+	+	-	+	-
CAO3-4-1	Carbon Steel	+	+	-	+	-
CAO3-4-8	Carbon Steel	+	-	-	+	-
CAO3-3-6	Ferralium 255	+	-	-	+	-
CAO3-4-5	Ferralium 255	+	-	-	+	-
CAO3-5-3	Ferralium 255	+	-	-	+	-
CAO3-2-7	Ferralium 255	+	-	-	-	-
CAO3-1-1	Inconel 718	+	-	-	+	-
CAO3-3-3	Inconel 718	+	-	-	+	-
CAO3-3-5	Inconel 718	+	-	-	+	-
CAO3-3-8	Inconel 718	+	-	-	+	-
CAO3-2-5	Zircaloy-4	+	-	-	+	-
CAO3-3-4	Zircaloy-4	+	-	-	+	-
CAO3-5-1	Zircaloy-4	+	-	-	+	-
CAO3-5-6	Zircaloy-4	+	-	-	+	-

a. 316L denotes Type 316L stainless steel and 304L denotes Type 304L stainless steel.

Table 8. Microbial types isolated from the surface of coupons retrieved from the 10-ft depth.

Sample	Metal Type	Microbial Characteristics: Heterotroph	SRB	Denitrifier	Acid Producer	*T. thio.*
CAO4-3-7	304L [a]	+	-	-	+	-
CAO4-4-1	304L [a]	+	+	-	+	-
CAO4-4-5	304L [a]	+	-	-	+	-
CAO4-4-8	304L [a]	+	-	-	+	-
CAO4-5-6	316L [a]	+	-	-	+	-
CAO4-5-7	316L [a]	+	-	-	+	-
CAO4-6-2	316L [a]	+	-	-	+	-
CAO4-6-3	316L [a]	+	-	-	+	-
CAO4-1-1	316L [a] Welded	+	-	-	+	-
CAO4-3-4	316L [a] Welded	+	-	-	+	-
CAO4-3-5	316L [a] Welded	+	-	-	+	-
CAO4-2-7	316L [a] Welded	+	-	-	+	-
CAO4-2-2	Aluminum	+	+	-	+	-
CAO4-2-3	Aluminum	+	-	-	+	-
CAO4-3-1	Aluminum	+	-	-	+	-
CAO4-3-2	Aluminum	+	-	-	+	-
CAO4-4-3	Beryllium	+	-	-	+	-
CAO4-2-5	Beryllium	+	+	-	+	-
CAO4-3-3	Beryllium	+	+	-	+	-
CAO4-4-7	Beryllium	+	-	-	+	-
CAO4-1-3	Carbon Steel	+	-	-	+	-
CAO4-2-6	Carbon Steel	+	-	-	+	-
CAO4-4-4	Carbon Steel	+	-	-	+	-
CAO4-6-1	Carbon Steel	+	-	-	+	-
CAO4-1-2	Ferralium 255	+	-	-	+	-
CAO4-3-8	Ferralium 255	+	-	-	+	-
CAO4-4-6	Ferralium 255	+	-	-	+	-
CAO4-5-3	Ferralium 255	+	-	-	+	-
CAO4-2-4	Inconel 718	+	-	-	+	-
CAO4-4-2	Inconel 718	+	-	-	+	-
CAO4-5-2	Inconel 718	+	-	-	+	-
CAO4-5-4	Inconel 718	+	-	-	+	-
CAO4-2-1	Zircaloy-4	+	-	-	+	-
CAO4-3-6	Zircaloy-4	+	-	-	+	-
CAO4-5-1	Zircaloy-4	+	-	-	+	-
CAO4-5-5	Zircaloy-4	+	-	-	+	-

a. 316L denotes Type 316L stainless steel and 304L denotes Type 304L stainless steel.

Table 9. Analytical chemistry spectrochemical analysis.

Record No.	01-D-3	Log No.	0102204
Analyzed by	BRB	Project	Be Soil
Sample activity	none	Method	12702 XRD

Sample Name	X-ray Diffraction Results
Be Dirt	SiO_2 (Quartz) is the major crystalline component of this sample. $CaCO_3$ (Calcite) and Na $(AlSi_3O_8)$ (Albite) are present as minors. The following compounds are possibly present: SiO_2, $(Na_{0.75}K_{0.25})(AlSi_3O_8)$ Anorthoclase), $CaMgSi_2O_6$ (Diopside), $Na_2BeSi_2O_6$ (Chkalovite) and $Cu_{0.6}Fe_{1.4}Ni_{0.65}Zn_{0.35}O_4$. Minor unidentified components are present. Amorphous material is present.

Table 10. Analytical chemistry analysis final report for Be-dirt.

Log Number	01-02204	Date Received	February 20, 2001	Date Approved	April 18, 2001
MSA mR/hr	COLD	Hazard Index	1E4	PCBs>50 ppm	NO

Analysis	Lab Spl ID	Field Spl ID	Method	Analyst	Results
Beryllium	1AI26	DIRT SN-15, SN-16	42900	RHH	1.95766E+04 mg/kg
Chloride	1AI26	DIRT SN-15, SN-16	28202	NWJ	3.51713E+01 ug/ml
Flouride	1AI26	DIRT SN-15, SN-16	28201	NWJ	1.26405E-01 ug/ml
Iron	1AI26	DIRT SN-15, SN-16	42900	RHH	1.94574E+04 mg/kg
Manganese	1AI26	DIRT SN-15, SN-16	42900	RHH	4.38343E+02 mg/kg
Sulfur	1AI26	DIRT SN-15, SN-16	42900	RHH	2.28941E+02 mg/kg

6. FIELD MONITORING

The LTCD test calls for field monitoring at the berm to collect data on precipitation, soil moisture, soil-water chemistry, soil-gas composition, and soil temperature. All field monitoring called out by the test plan is necessary to correlate the corrosion rate data with the SDA environment. Soil moisture and soil chemistry are the strongest influencing factors in underground corrosion at the test location. Field monitoring data were collected during the first year of the test, as documented in the *Long Term Corrosion/Degradation Test Year Results* (Mizia et al. 2000). The LTCD test was not funded during the second year, so none of the pertinent data were collected. Field monitoring was included in the original work scope for the third-year effort, but the funding was curtailed before any monitoring was accomplished. A rain gauge is in place at the nearby weather station. Neutron probe access tubes are in place in the berm for soil moisture monitoring as are suction lysimeters for collection of soil-water samples and gas ports for soil gas collections. No data collection during the second and third years of the test severely limits the ability to accurately assess fate and transport mechanisms in the SDA environment.

6.1 Precipitation Monitoring

On average, the region where the berm is located receives 21.97 cm (8.65 in.) of precipitation a year (National Oceanic and Atmospheric Administration records). Spring and summer rainstorms generally supply most of the precipitation, but soil moisture and total infiltration are impacted greatest by moisture supplied by snowmelt. Snowmelt at the berm generally occurs in February and March, at a time when the water is free to infiltrate into the ground with little opportunity for evapotranspiration. The impact of snowmelt on infiltration is increased in areas where the water collects and is lessened in areas where the water runs off.

Precipitation is measured on the berm with an all-weather rain gauge at the northeast corner of the EBTF. The rain gauge at the EBTF is currently in need of repair (the heater element is not functioning) so any frozen precipitation may not be accurately measured. Again, funding reductions have affected both the quantity and quality of the data. For the purposes of this report, the INEEL average annual precipitation of 8.65 in. per year, as measured and recorded at the INTEC, will be used (DOE-ID 2000).

6.2 Soil Moisture Testing at the Berm

The hydrologic setting for the corrosion test is an important parameter that affects corrosion because evaluated soil moisture and water table position have been found to be correlated with increased corrosion (Durr and Beavers 1998). The potential impact of hydrology on the corrosion rates of the coupons is evaluated in the following discussion.

The berm where the corrosion testing is being conducted is located in the vadose zone approximately 177 m (580 ft) above the Snake River Plain Aquifer in southeastern Idaho. The vadose zone consists of 3 to 6 m (10 to 20 ft) of fine-grained aeolian deposited sediments overlaying hundreds of feet of thin basalt flows containing occasional sedimentary interbeds and rubble zones. The aquifer is located in yet deeper basalt flows.

Three 3-m (10-ft) neutron probe access tubes were installed in the test berm near the coupon burial sites (see Figure 40) for the purpose of monitoring soil moisture. The neutron probe access tubes are designated in Figure 40 as NP1, NP2, and NP3. The tubes were installed by drilling a 2-in. auger hole, placing a 1.9-in. (outer diameter) stainless steel casing down the hole, and filling the annular space with sieved native sediments. The backfill was packed into the annular space to ensure that the neutron monitoring tube did not become a conduit for moisture movement into the berm. The installation was outside the 6-ft diameter holes drilled for the coupon installation.

Moisture monitoring was initiated in January 1998 and continued through October 1998. The results are reported in the first year report (Mizia et al. 2000). No monitoring via neutron probes has occurred since then, for lack of funding. The limited moisture data that is available suggests that infiltration into the berm is much less than that occurring in the SDA. This is believed to result from density differences. The density of the berm greatly exceeds the density of the SDA cover soils.

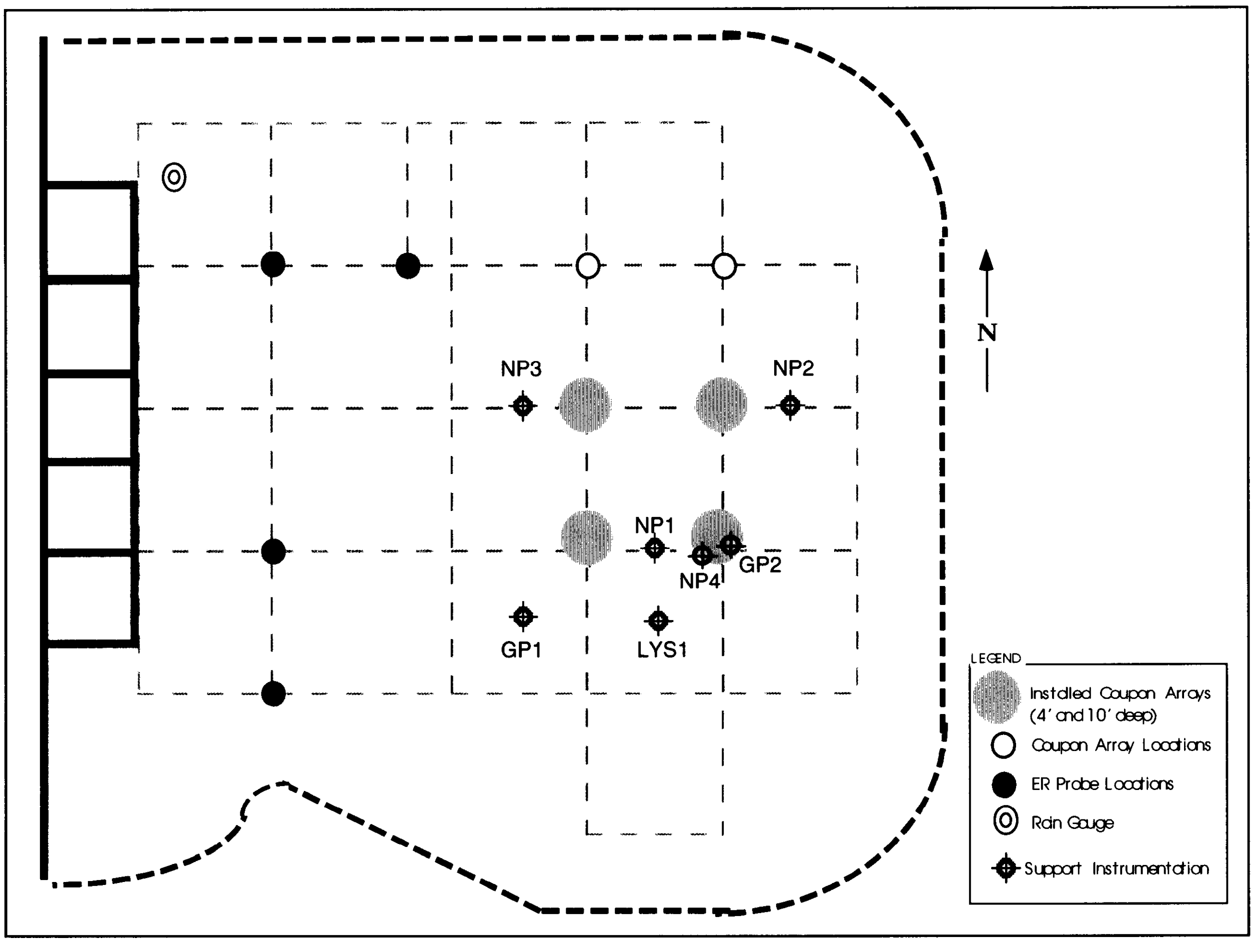

Figure 40. Support instrumentation installation locations.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Summary of Third-Year Corrosion Results

Of the various metals subjected to corrosion testing and evaluated after 3 years of underground exposure, carbon steel and beryllium exhibited the highest corrosion rates with higher corrosion rates on coupons at greater depth. Pitting caused by corrosion was evident on the carbon steel, beryllium, and aluminum coupons. Corrosion rates for coupons composed of aluminum, austenitic stainless steel (Type 304L and Type 316L), Inconel 718, and Ferrallium 255 were low but detectable. Corrosion rates for the Zircaloy-4 coupons were very low, below detection limits in most cases.

7.2 Possible Long Term Trends

As the LTCD test project progresses in future years, it will be possible to draw conclusions that are more definitive than can be drawn from the 1- and 3-year results. The conclusion by Nagata and Banaee (1996) continues to be reinforced and that the standard corrosion rates for stainless steels and carbon steel being used in the SDA performance assessment may be considerably higher than actual corrosion rates in SDA soils. Of greater concern, though, is beryllium, a metal for which there are no known underground corrosion data available except those being produced by this study. The beryllium corrosion rate and the subsequent release rate of C-14 will be the driver for fate and transport assessments for the SDA.

Additional investigation is required to further understand the differences between corrosion conditions at the LTCD test site and conditions across the SDA.. Such environmental conditions include higher moisture levels and temperatures, the presence of chloride, and the proximity of activated metals of various compositions. Coupon retrieval and evaluation efforts must continue according to the schedule specified in the test plan. In addition, testing efforts must be supplemented by monitoring of LTCD and SDA environmental conditions. Comparing and assessing the importance of those differences then require application to reduce the uncertainties in the source term being used in the SDA performance assessments and analyses and in the remedial investigations and baseline risk assessments conducted by Environmental Restoration.

7.3 Pitting

The contributions of pitting rather than uniform corrosion, particularly with beryllium, are significant. In instances where pitting occurs, the coupon evaluations must include pit characterization (i.e., pit geometry) for the results to be meaningful. Possible methods for pit characterization include surface profiling (using vertical scanning interferometry) and metallography. A "pit factor" (the ratio of the depth of the deepest pit to the average depth of general corrosion) should be determined for each coupon that shows evidence of pitting. Short of pit characterization, the analysis might be more meaningful if the results were presented in terms of a rate of total metal "wastage" instead of a corrosion rate in mils or millimeters per year. The total metal wastage would be based on a measurement of weight change as a percent of the initial weight of the coupon.

Of the metals being tested in the LTCD test project, beryllium is by far the most interesting, in terms of corrosion results and the potential impacts to the radionuclide fate and transport risk assessments and analyses. The LTCD test project is apparently the first controlled field study ever conducted exposing beryllium metal to underground corrosion conditions. The results so far are significant, with corrosion rates higher and pitting damage greater than initially expected. That, combined with the need to understand how the environment at the SDA and irradiation of the beryllium directly impacts the corrosion rates, underscores the importance of continuing the LTCD test project as scheduled in the test plan. Future recovery and evaluation of beryllium coupons will add greatly to the knowledge base on beryllium corrosion. It also will provide data to look closer at the differences in corrosion rates at different burial depths. The nature of the corrosion products from beryllium metal is a vital aspect of the testing and analysis. The results reported here include a limited analysis of the soil adhering to the beryllium coupons, but other analysis tools could be applied to examine more closely surface corrosion effects and corrosion products and define corrosion initiation and propagation. So far, funding for the project has not been sufficient to support a study of beryllium cleaning and measurement uncertainties. The results of such a study would add credibility to the beryllium corrosion rates being produced by the LTCD test project.

Of ultimate importance is the need to correlate the results of the beryllium corrosion testing with the many activated Beryllium S200F blocks disposed of in the SDA. Of particular concern is the long-lived radioactivity of the C-14 contained in beryllium, the shorter-lived tritium, and other isotopes. Of interest is the ongoing monitoring of the 1993 disposal location of beryllium blocks in the SDA. A progress report of this monitoring has been published (Ritter and McElroy 1999) and describes the findings of soil gas and aboveground air monitoring between 1994 and 1999. All work related to identifying a site-specific beryllium corrosion rate and identifying the corrosion products impacts the SDA source term calculations and risk assessments.

7.4 Soil Characteristics

The test plan calls for soil characterization, soil moisture monitoring, and other monitoring at the LTCD test location (the berm) and at the SDA, for comparison and data correlation purposes. Funding limitations have significantly impacted those efforts. Additional soil characterization is required at both locations, and consistent, uninterrupted soil moisture monitoring and other monitoring also is required. Additional studies should compare soil moisture contents of the berm and the SDA. Additional soil resistivity measurements should be taken on the test berm at different times of the year to account for different soil moisture contents. Soil characteristics such as pH and composition require further investigation, comparisons, and documentation. Additional testing is required to adequately compare variable soil moistures within the SDA to the LTCD test location at required by the test plan (Adler-Flitton et al. 2001).

7.5 Microbiological Factors

Evidence was found of microorganisms on the surface of all the examined coupons. Results indicate an increasing presence of organic acid producing microbial species colonizing the coupon surfaces together with sulfate-reducing bacteria (SRB) colonization of carbon steel, aluminum, and in particular beryllium. Six of the seven coupons with the highest corrosion rates also showed SRB colonization. The environment is suitable for the promotion of microbiologically induced corrosion (MIC). By inference then, MIC should be expected at the SDA and may have significant impact on the calculated rate of metal corrosion. The results of the microbial study represent a beginning point from which additional investigations should be performed in conjunction with future coupon recoveries and examinations. Further investigations should include the following tasks:

- Perform soil gas analysis biannually at the berm and compared to SDA soil gas analyses

- Examine coupon surfaces upon recovery for biofilm development using both mechanical and recent biomolecular techniques

- Identify each microorganism genus and species
- Conduct bacterial counts for SRB and other microbes of interest for comparison with MIC criteria specified in the literature
- Compare microbial characteristics at the berm with those at the SDA.

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